ENGI 128

INTRODUCTION TO ENGINEERING SYSTEMS

Lecture 17: Finite State Machines, Behavior-Based Programming, Final Design Challenge

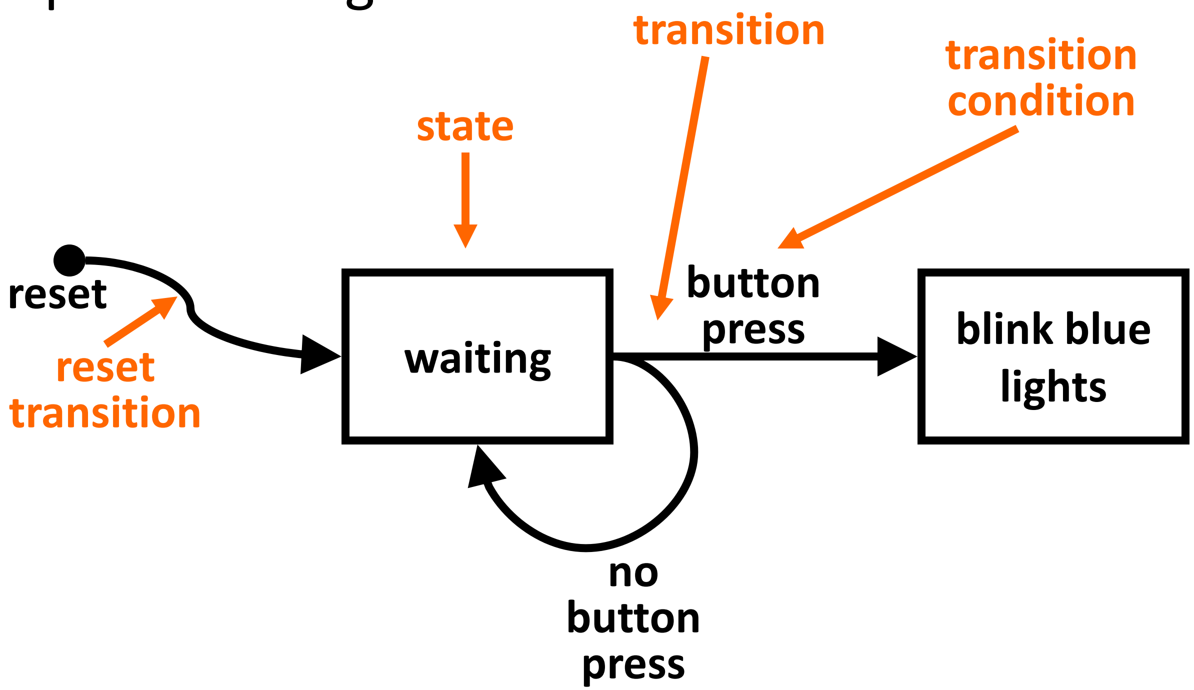
"Understand Your Technical World"

Finite-State Machines (Discrete Finite Automata)

Finite-State Machines (Discrete Finite Automata)

It sounds complicated, but you've been using them for a while:

Sample FSM diagram:

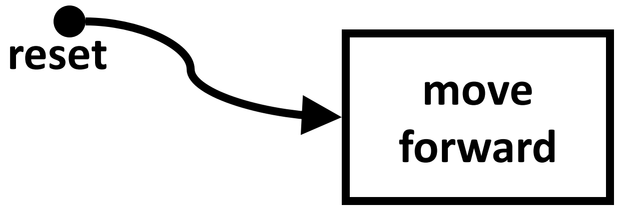


Q: What does this program do?

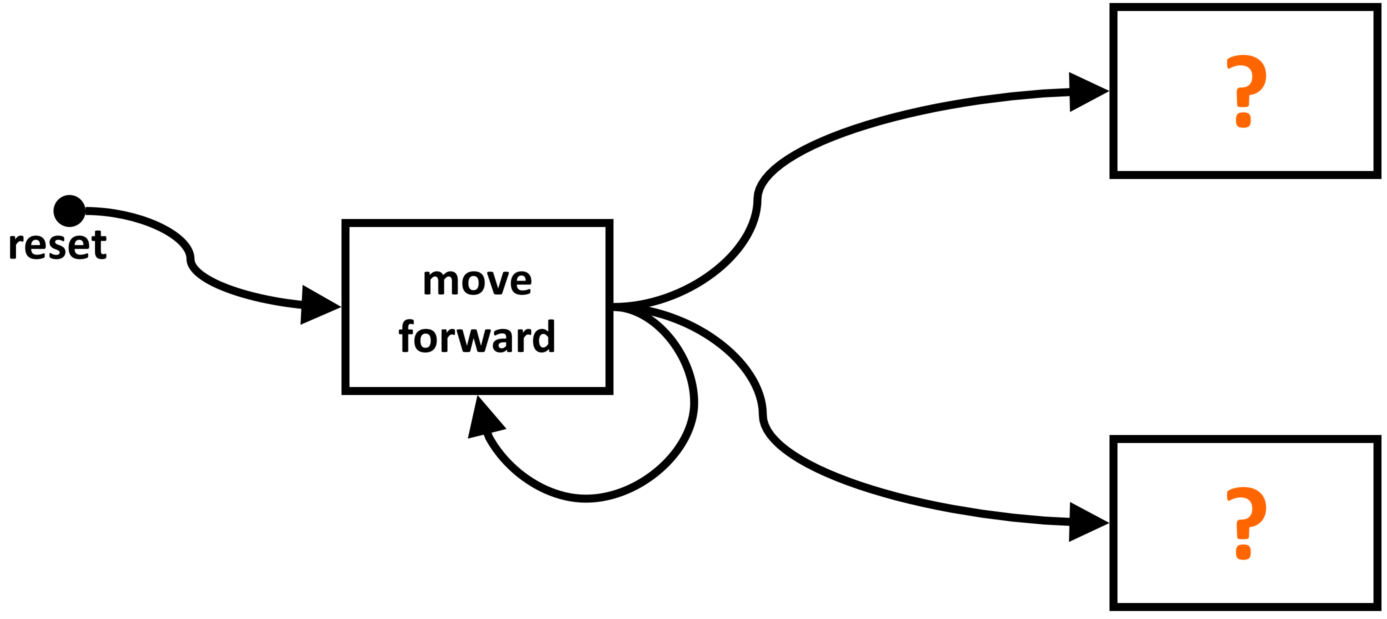
An Example FSM: Wall detection

[Demo dark avoid code on robot]

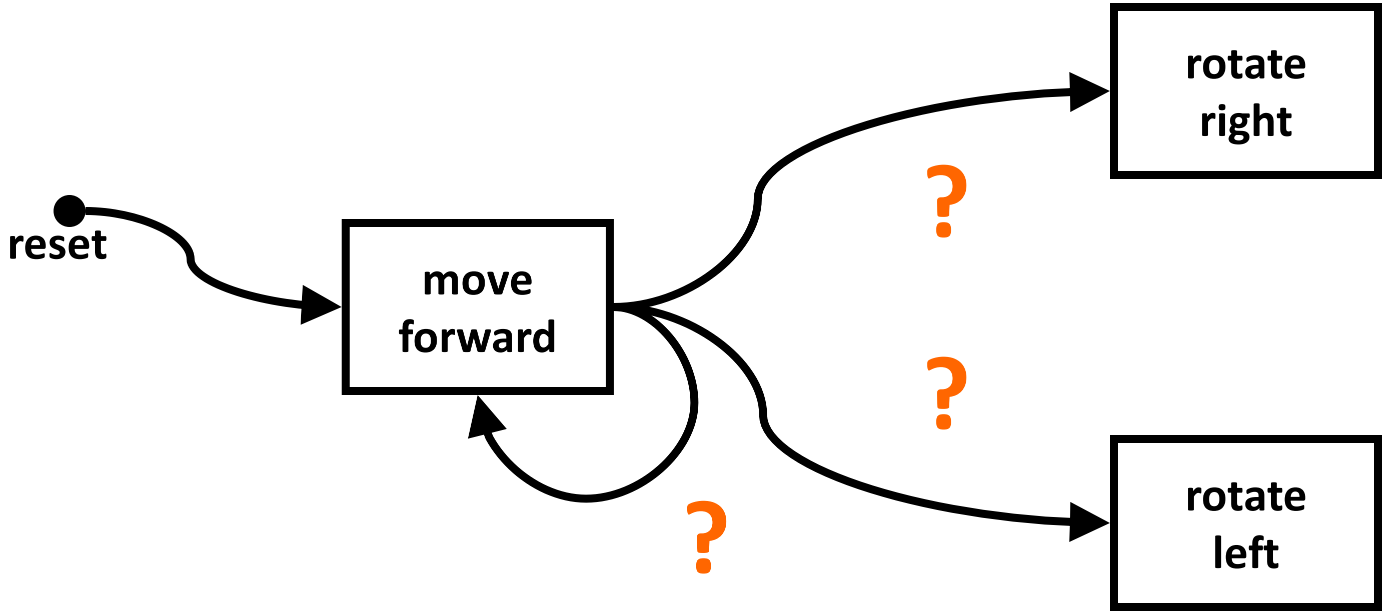
An Example FSM: Wall detection



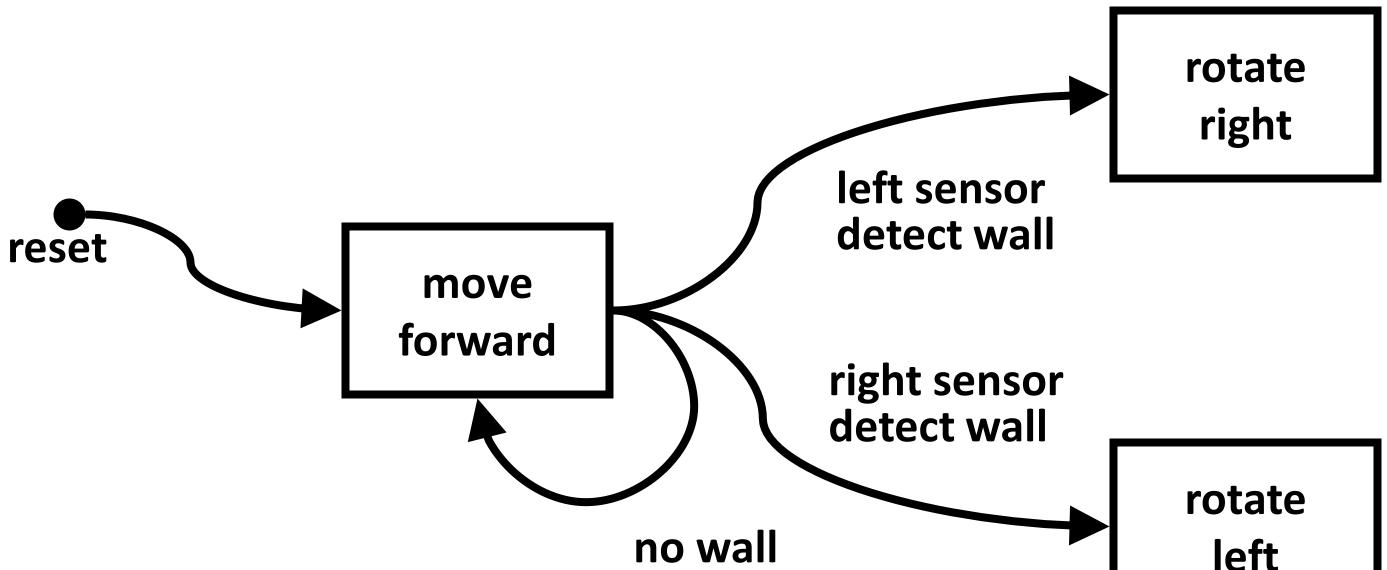
An Example FSM: Wall detection



An Example FSM: Wall detection

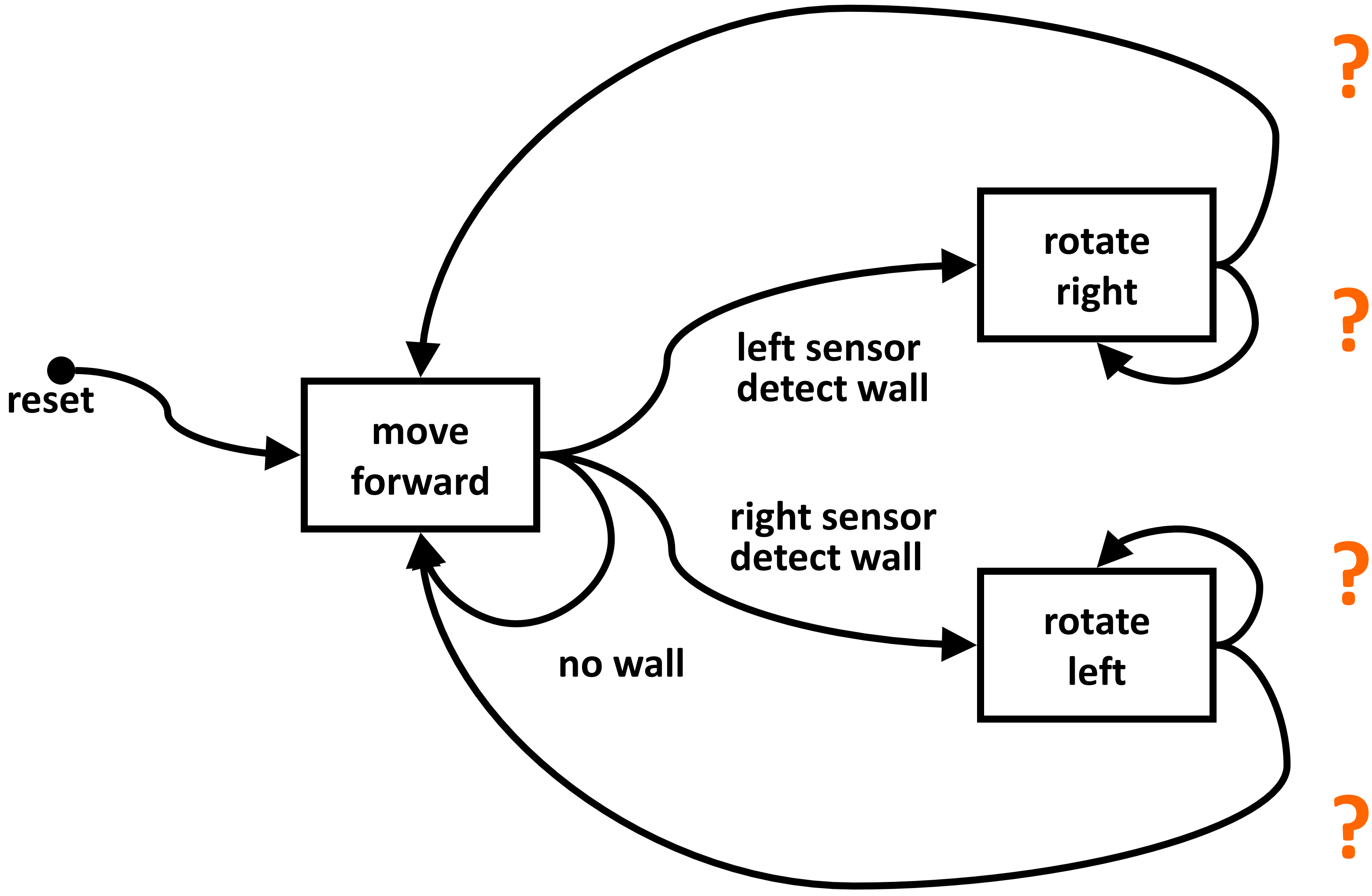


An Example FSM: Wall detection

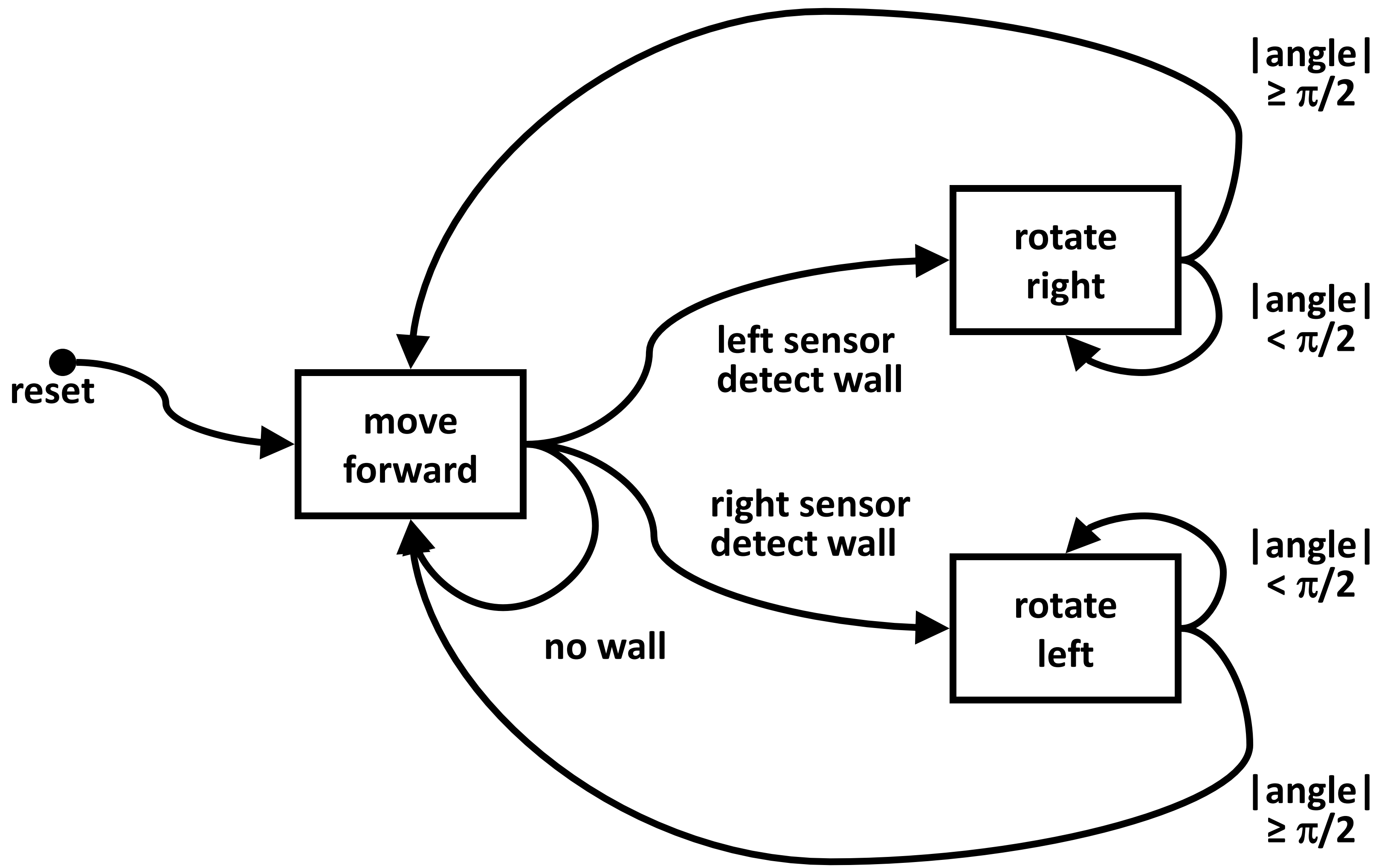


Q: Note that the left sensor triggers a right rotate. Does this make sense?

An Example FSM: Wall detection



An Example FSM: Wall detection

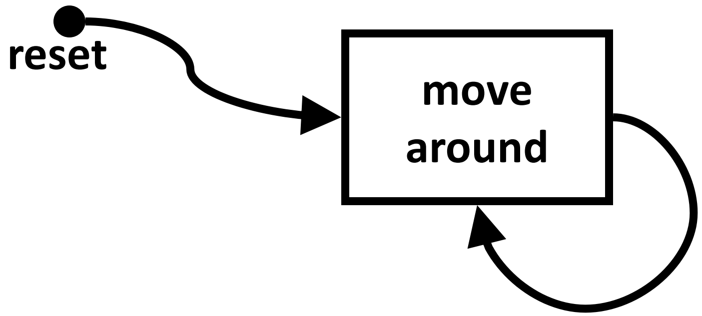


[Review dark avoid code in editor]

Finite-State Machines (Quidditch Version)

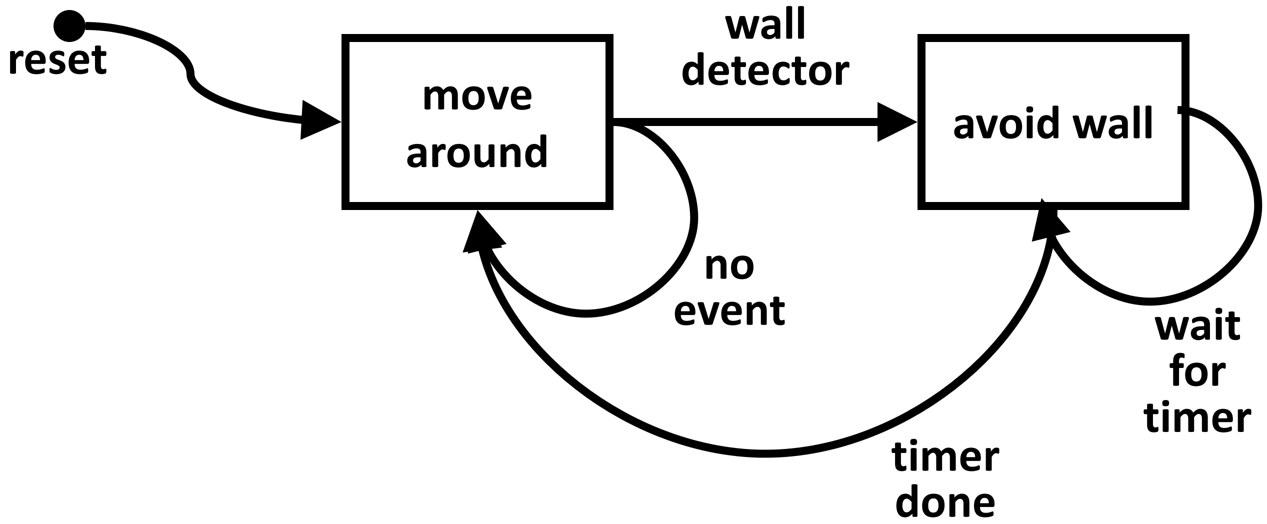
For example

Let’s say you are programming a “Seeker” robot…



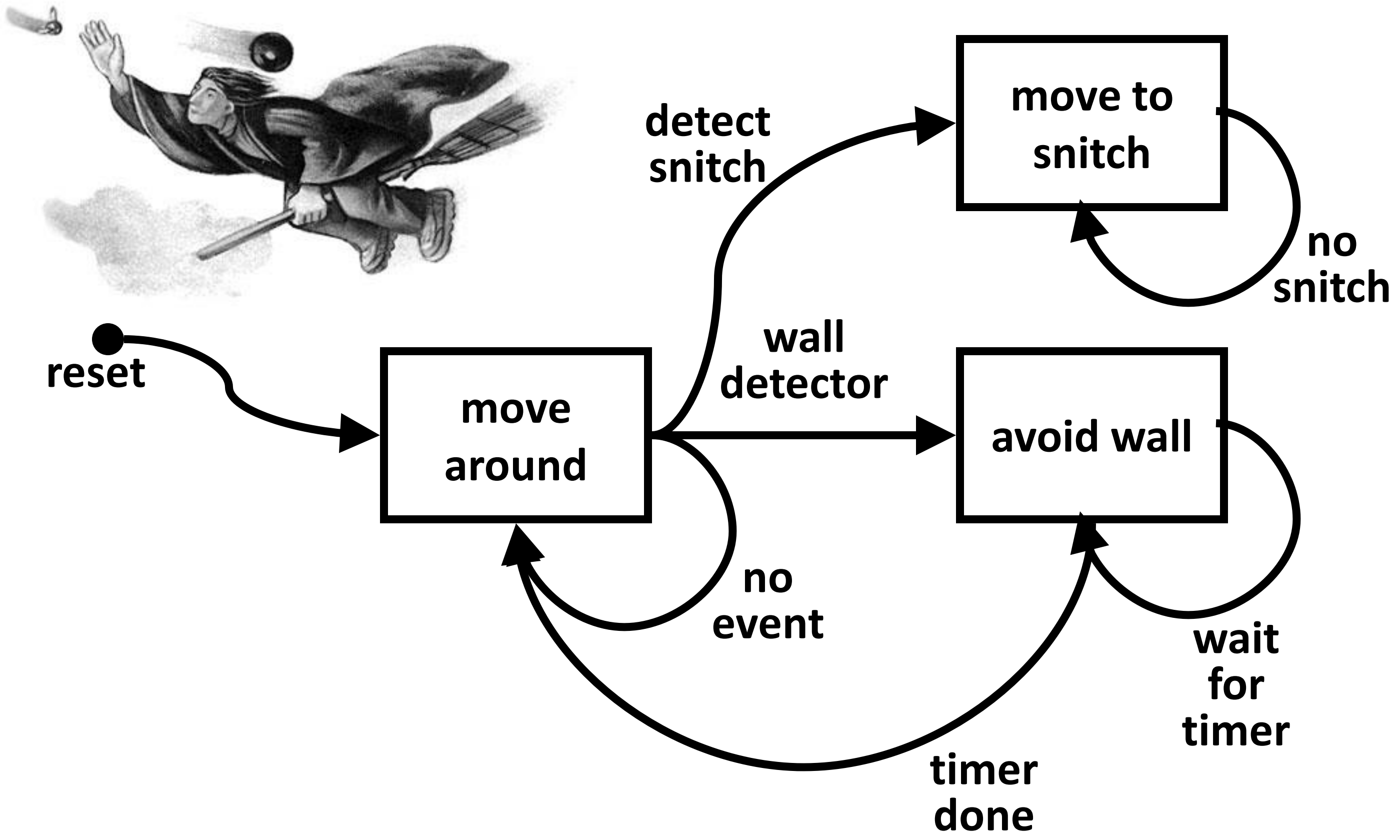
For example

Let's say you are programming a "Seeker" robot…



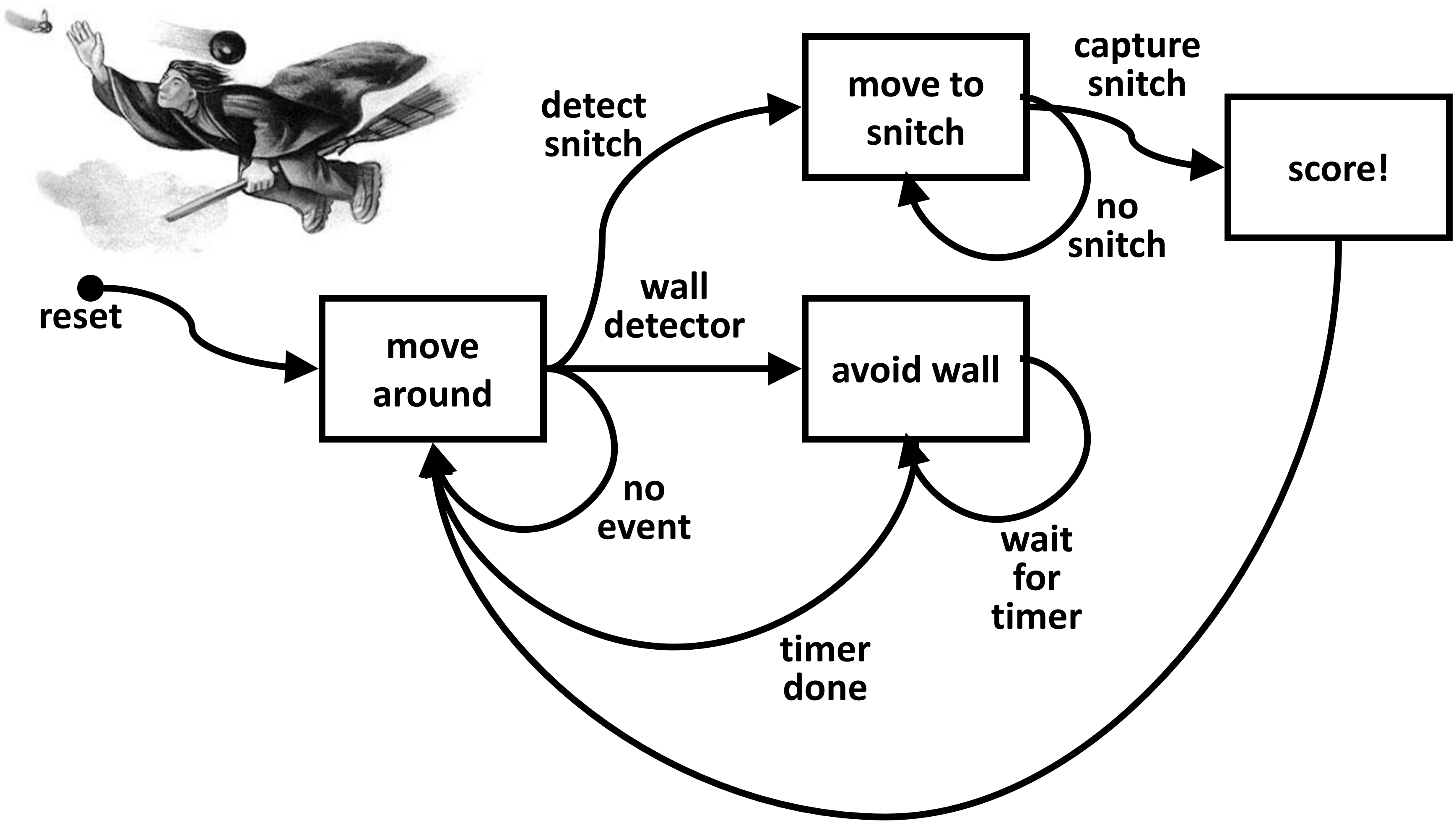
For example

Let’s say you are programming a “Seeker” robot…



For example

Let's say you are programming a "Seeker" robot…



Yikes!

Don’t worry, it looks simpler in code…

Behavior-Based Robot Programming

Behavior-Based Control

A behavior is a small program (or finite-state machine) that reads the sensors and controls the robot

- Each behavior only does ***one simple*** thing
- Each behavior has access to all the sensors of the robot and produces motor outputs (tv, rv, active)

Only one behavior can be active at a time

- There is a *prioritization* of behaviors
- More important ones override, or ***subsume***, less important ones

An Example Behavior-Based Program

Follow a robot

- Sensor: IR Communications
- Behavior: Follow another robot

Avoid Obstacles

- Sensors: Bump sensor to detect wall
- Behavior: Move away from wall

Wander

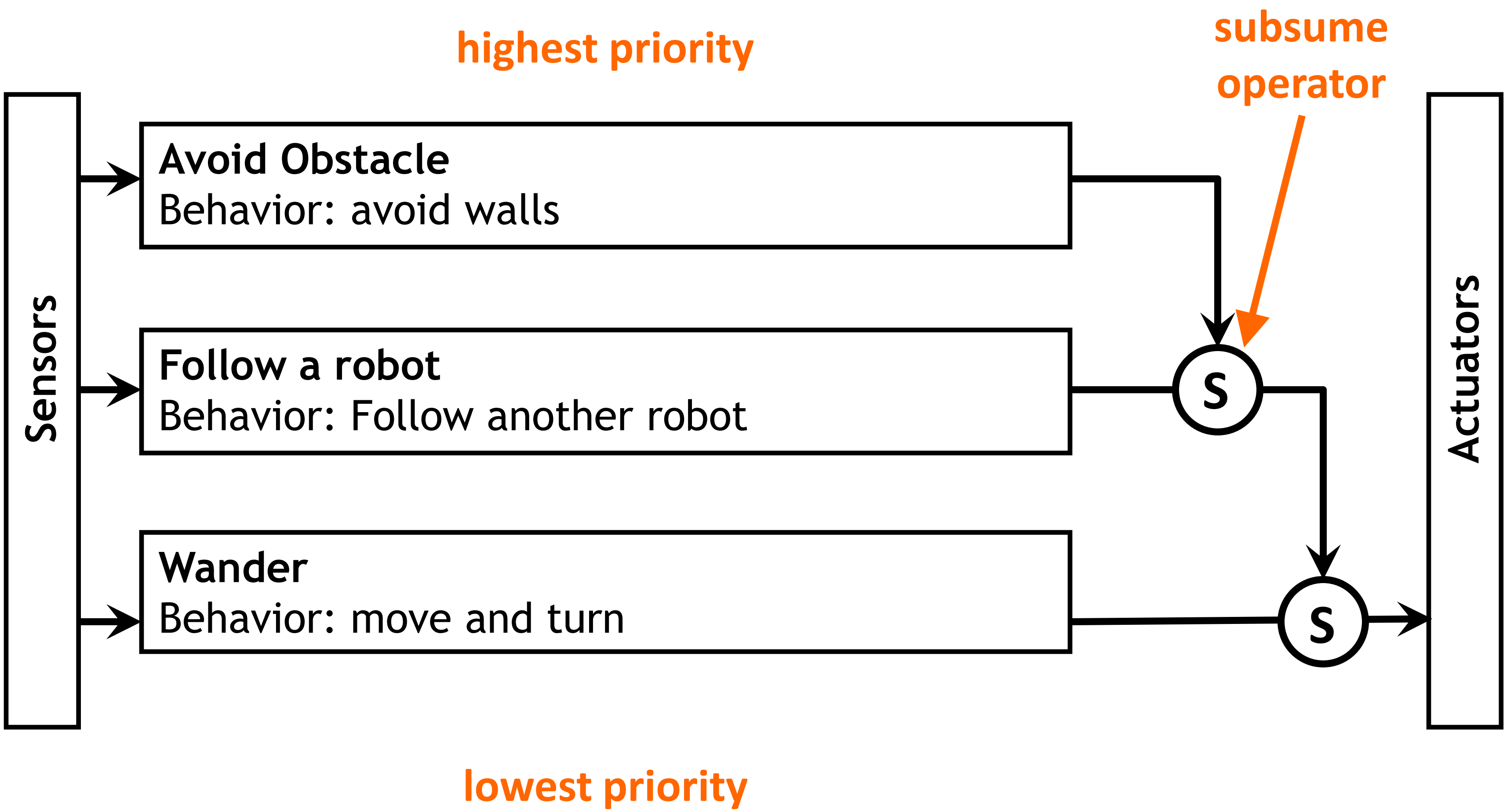
- Sensor: Encoders
- Behavior: Move forward and turn

Q: Which behavior should have the highest priority?

Q: Which behavior should have the lowest priority?

Combining Behaviors

We combine behaviors by overriding, or ***subsuming*** lower-priority behaviors if a higher-priority behavior becomes active



Genghis

The behavior-based poster child

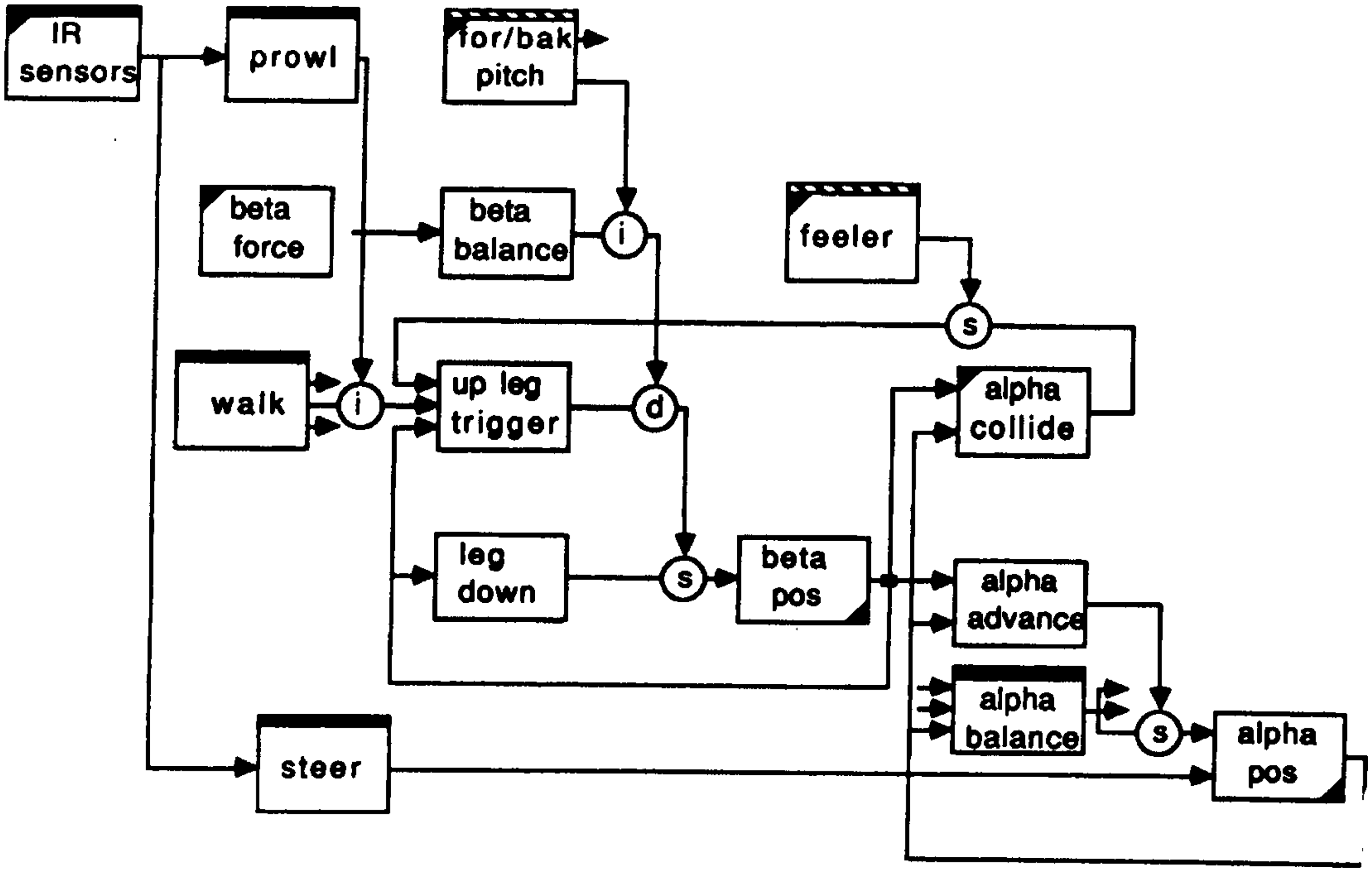
Really simple hardware

- 6 legs, 2 motors per leg
    - α-motor for forward/back, β-motor for up/down
- 2 bump sensors (feelers)
- 2 ground detection sensors (switches)
- 6 heat sensors (but they weren't used for walking)

R. Brooks. "A Robot that Walks; Emergent Behavior from a Carefully Evolved Network", ICRA 1989

Genghis in Action

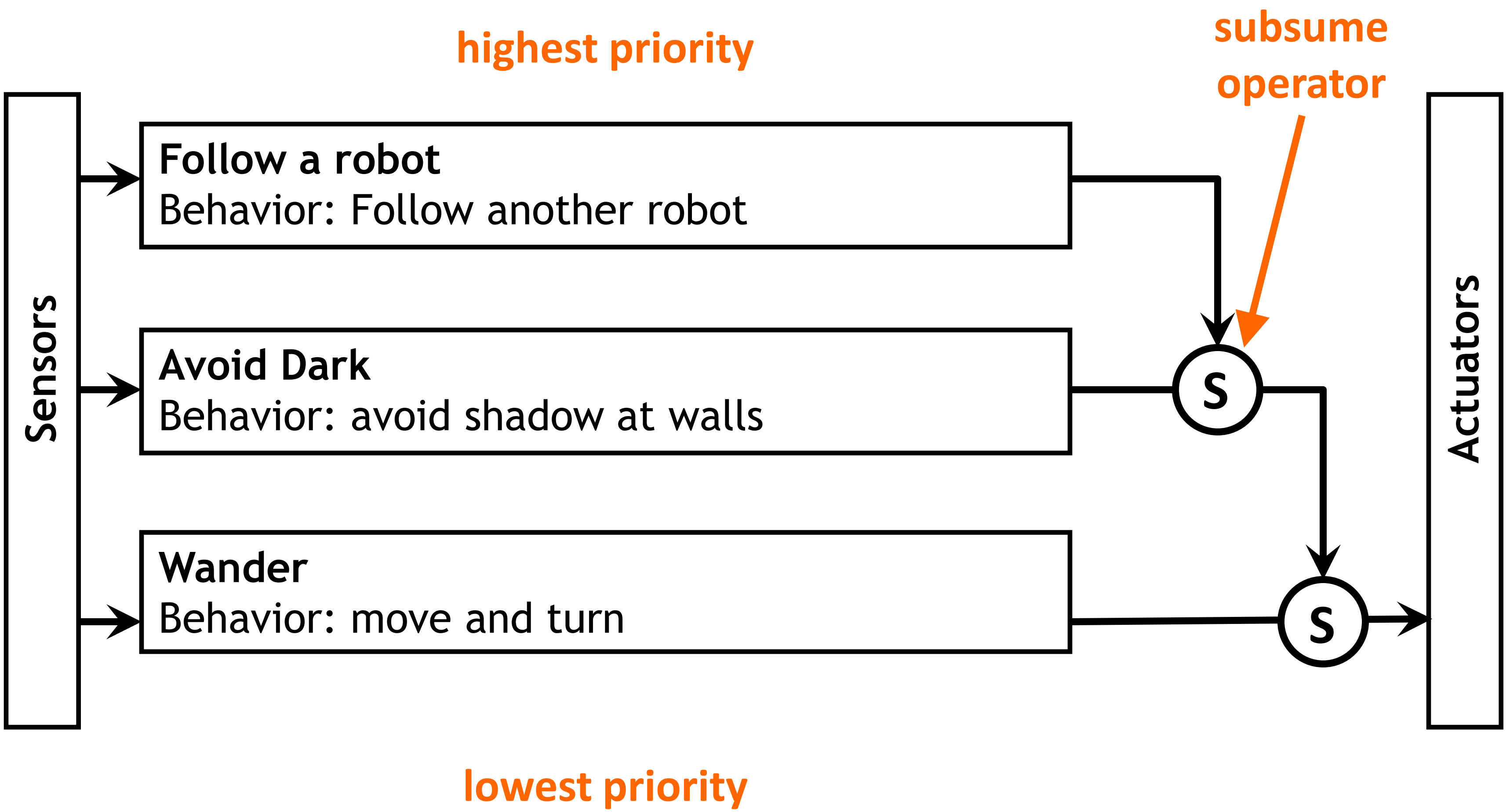
Subsumption Architecture



R. Brooks. “A robust layered control system for a mobile robot”, ICRA 1986

Combining Behaviors

We combine behaviors by overriding, or ***subsuming*** lower-priority behaviors if a higher-priority behavior becomes active



Great, but how to you program this?

You can abstract this a bit more:

- Write each behavior as a function that returns a tuple of (tv, rv, active)
- write a **beh_subsume(high_priority, low_priority)** function that returns the high_priority or low_priority output, depending on which has active == True
- If neither behavior is active, it returns the **INACTIVE_BEH** output

```
INACTIVE_BEH = (False, 0.0, 0.0)
wander_out = wander(foo, bar)
gps_out = gps_navigation(bang, zoom)
obstacle_out = obstacle_avoidance(bif, bop)

beh = beh_subsume(gps_out, wander_out)
beh = beh_subsume(obstacle_out, beh)
velocity.set_tvrv(beh_get_tv(beh), beh_get_rv(beh))
```

Great, but how to you program this?

There are several ways:

- Write each behavior as a function that returns a tuple of (active, tv, rv)
- Write getters to extract the different parts of the tuple
- Use if statements to overwrite the outputs of lower-priority behaviors

```
INACTIVE_BEH = (False, 0.0, 0.0)
wander_out = wander(foo, bar)
gps_navigation_out = gps_navigation(bang, zoom)
obstacle_avoidance_out = obstacle_avoidance(bif, bop)

beh = INACTIVE_BEH
if beh_get_active(wander_out):
    beh = wander_out
if beh_get_active(gps_navigation_out ):
    beh = gps_navigation_out
if beh_get_active(obstacle_avoidance_out):
    beh = obstacle_avoidance_out
velocity.set_tvrv(beh_get_tv(beh), beh_get_rv(beh))
```